WHAT ARE WE LEARNING FROM SPACE?

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FOR TEACHERS, ADMINISTRATORS,
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INTRODUCTION

When I was invited to speak to you, I was happy to note that the title suggested was broad in scope. This leaves me free to choose somewhat like Vice President Johnson's airplane pilot. The Vice President instructed him, "Take me where you will, we have problems everywhere." With comparable freedom of choice, I plan to discuss with you educators a few of the things of a scientific nature we are learning from space activities.

UNMANNED SPACECRAFT

May I start with a moving picture? This movie is introduced by Dr. Hugh L. Dryden, Deputy Administrator of NASA and a world-renowned scientist. Better than just words, this film will give you some idea of how NASA is carrying out scientific explorations of space. (Movie)

BEYOND THE SOLAR SYSTEM

The realm of space research knows no limits. Let us start way out beyond the solar system and work toward home. No, we have not yet sent probes beyond our Sun's influence. We have received signals from one man-made space probe 22,000,000 miles away, still well within our solar system. We have, however, learned a great deal simply by sending spacecraft outside Earth's atmosphere which stops radiation, over much of the electromagnetic spectrum, from reaching the Earth. I will give two examples.

Gamma Rays

Explorer XI, shown here, (slide 1) has sent us some informative data on gamma rays. Gamma rays, as you know, are a high-energy form of light. They carry no charge, so they are not bent by magnetic fields. They come from their sources in straight lines. The next slide (slide 2) is a map of the celestial sphere showing the directions from which Explorer XI observed gamma rays coming. These observations are significant in relation to the steady-state concept of the universe. This concept includes the idea that matter is continuously created and destroyed through the interactions of matter and antimatter. The most pleasing form of this concept imagines matter and antimatter being created at equal rates. Were this the case, it is estimated that Explorer XI would have reported about 3,000 gamma-ray events per hour. In contrast, it reported only 2.4 per hour. This observed rate is far short of the 3,000 per hour for the symmetrical, steady-state concept, but it is about twice the rate expected from cosmic rays alone.

Ultraviolet Radiation

Another example concerning far space has to do with ultraviolet radiation from stars as observed by spectroscopes carried above our atmosphere by rockets. A surprising result is shown on the next slide (slide 3) where energy is plotted against wavelength. For a certain type of young, hot stars, such as this, it was expected that the ultraviolet energy would approximate the upper curve. The observed energy falls far short of the expected energy at the shorter wavelengths.

These two examples reminded Dr. Goett, Director of our Goddard Space Flight Center, of the quotation, "The terrible tragedy of science is the horrible murder of beautiful theories by ugly facts."

Orbiting Astronomical Observatories

More sophisticated observations of far space are being planned. Orbiting Astronomical Observatories to carry a variety of experiments are now being built on contract for NASA. (Slide 4) To illustrate the technological refinement necessary in these telescope-carrying satellites, I will quote one requirement. These satellites must point steadily at selected stars or other points in space within 0.1 second of arc. That is equivalent to pointing at a basketball in San Francisco 400 miles away. These observations, operating outside our obscuring atmosphere, will increase the rate at which astrophysical theories are murdered and will stimulate the birth rate of new ones.

OUR SUN

Importance

Now let us move in to the nearest star, our Sun. You science teachers need not be reminded of the importance of this Sun. We could no more live without it than without our Earth. As a bonus, the Sun's continuous, gigantic atomic reactions may offer us hints for generating power by controlled nuclear fusion here on Earth.

Particles From the Sun

The next slide (slide 5) shows a sounding rocket on its way to collect some samples from the Sun. No, this rocket did not go anywhere near the Sun. It just went above the atmosphere and above the Earth's magnetosphere in the polar regions where the magnetosphere dimples down relatively close to the Earth. The rocket carried blocks of photosensitive emulsion similar to the material used on camera films. After flight the emulsions are recovered and developed. Two samples are shown on the next slide. (Slide 6) The tracks you see were left by impinging particles. The sample on the left was exposed during a period of solar quiet, while the one on the right was exposed in the middle of a major auroral display related to a class 3 solar flare. The increased particle frequency is obvious. From tracks such as these the experts can determine the characteristics of the various particles and derive charts such as this. (Slide 7) These bars depict the relative abundances of particles which had been part of the Sun 30 minutes earlier.

Effects of Solar Flares

There is continuous, tremendously vigorous, boiling and erupting of the Sun's surface. A spectacular feature is solar flares such as shown in the next slide (slide 8) on the left. The Earth is superimposed to scale to illustrate the gigantic size of these flares. They are associated with sunspots such as can be seen on the right. The effects of such activity reach out way beyond the visible flares and influence the interplanetary space through which the Earth is traveling.

The effects of solar storms on interplanetary space and on Earth are being studied by a number of spacecraft such as these. (Slide 9) They carry different instruments and fly various orbits to suit the needs. (Slide 10) Pioneer V is the one with the record of sending us information from 22,000,000 miles out. Large as this distance is, it is minute compared to the cosmos. Electromagnetic signals transmitted by a galaxy 6,000,000 years ago are only now being received on Earth by optical and radio telescopes. You see, we have plenty of space in which to extend our research. We are not fenced in. Explorer X went out some 145,000 miles; Explorer XII had an apogee of 48,000 miles.

These spacecraft have brought us some interesting information. Here is an example. The study of magnetic fields was the primary purpose of Explorer X. The next slide (slide 11) shows a sample of magnetometer readings. As the Explorer sped away from the Earth, over a 3-day period the data were received successively by the stations named along the bottom. Incidentally, you can imagine the planning, the organization, the training, the milli-second correlation, and the meticulous attention to detail required of many people around the world to produce a set of data like this.

You can see here that as the spacecraft sped farther from Earth the magnetic field decreased down to a general level around 20 gammas, but with considerable fluctuation. This general level is considerably higher than expected during solar quiet. At this time observatories on Earth noted a class 3 flare on the Sun. Twenty-eight hours later Explorer X noted this marked increase in magnetic field. At the same time, it reported an increase by several-fold of the density of plasma wind from the Sun. These are just two samples of information on interplanetary space obtained from instruments in spacecraft.

When these data are put together with many others, a tentative picture of some effects of solar storms begins to emerge. Remember, this is tentative; there still are alternate hypotheses and violent discussions. With that warning, let us proceed to the next slide. (Slide 12) As pictured here, it is hypothesized that a solar flare may reach out like a tongue and stretch magnetic field lines with it like loops of taffy. If these magnetic field lines are strong enough, cosmic rays will bounce off them, thus accounting for the decrease, called the "Forbush decrease," in cosmic rays striking the Earth following solar events.

At the same time, the stretched magnetic lines form this bottle. The bottle confines the plasma, this cloud of low-energy, charged particles, which erupted from the Sun. Particles of higher energy spiral around these magnetic field lines and are carried along with them. It is not clear where these particles get their energy, but by the time the electrons, protons, and neutrons reached Pioneer V, Explorer X, and Explorer XII they were traveling at speeds all the way from almost the speed of light on down.

As the tongue reaches farther from the Sun it may envelope the Earth and its magnetosphere as shown on the next slide. (Slide 13) The particles in the tongue are deflected by our own magnetic field. Few reach the Earth except in the polar regions where they probably contribute to the aurora. Whether the solar flares are a primary source of the particles in the Van Allen radiation belts is still controversial.

The energetic particles carried in these long tongues from solar flares are a distinct hazard to man in space. One objective is to learn to predict solar storms so they can be avoided.

Orbiting Solar Observatory

There is much more to learn about the Sun and its effects. A solar observatory (slide 14) was launched last March into a circular orbit about 350 miles above the Earth. Thus, it was above Earth's atmosphere. As it circled the Earth, Sun-sensing instruments actuated gas jets and kept the observatory's telescopes pointed at the Sun, reaiming them each time the satellite came into view of the Sun after passing behind the Earth. This orbiting solar observatory transmitted almost 1,000 hours of scientific information before it failed on May 22. It observed and reported data on more than 75 solar flares, mapped the gamma radiation from the sky, examined energetic particles in the lower Van Allen belt, monitored the Sun in a broad spectrum of X-ray and gamma radiation, and measured the changes with time of exposure in space of the properties of various temperature-control materials.

THE EARTH

Magnetic Field and Radiation Belts

Now let us move our attention yet closer to Earth, down to the Earth's own magnetic field. (Slide 15) One of the first phenomena discovered by spacecraft was the existence of the Van Allen radiation belts. These belts of particles spiraling back and forth along the Earth's magnetic lines have been well publicized. We have learned something of their average content. (Slide 16) We do not know from whence the particles come nor just why the population fluctuates. As indicated earlier, these factors may be closely related to solar storms. We must learn more about all these radiation phenomena to plan for safe flight of men into space and to plan communication and weather satellites for long useful lives.

Ionosphere

Even closer to Earth we come to the ionosphere, layers of ionized gas extending from roughly 40 miles to several thousand miles above the Earth. The ionosphere is of great practical importance because it reflects radio waves to make long-range radio communication possible. Several probes and spacecraft (slide 17) have told us something of the composition of the ionosphere. On this slide (slide 18), the dotted line shows what was expected, while the solid line shows what was found. The earlier estimate was based on the assumption that at these higher altitudes the main constituent of the atmosphere is atomic hydrogen. The discrepancy could be explained if there were a layer of helium at these altitudes between a lower layer of atomic oxygen and a higher layer of atomic hydrogen.

Satellite S-51 was launched on April 26 to learn more about the ionosphere. Though built at NASA's Goddard Space Flight Center and launched by NASA, this satellite includes six British experiments. It is the policy of the United States to share the peaceful benefits of space with all, and to provide other nations opportunities to participate in scientific studies.

Upper Atmosphere

Additional information on the upper reaches of the atmosphere is derived as a by-product of other missions. For example, when air resistance gradually slows down satellites, the air density can be calculated from the rate of deceleration. Probably most of you have seen Echo I (slide 19) flying around the world. It has been going around for almost 2 years now; in fact, on August 12 Echo will be 2 years old. It is 100 feet in diameter, but it weighs only 130 pounds. Thus, it is sensitive to air resistance and is a good indicator of air density. The next slide (slide 20) is a plot of the rate of increase of Echo's time per orbit expressed in seconds per day. An interesting point is the faster decay at the times of solar flares. The implication is that the solar flares heated the upper atmosphere, causing it to expand upward and thus temporarily increased the density at Echo's altitude of about 1,000 miles.

Solar Wind

Another force which reaches out to Earth is the pressure of solar radiation, or solar wind. Solar wind is evident from the way it alters satellite orbits. The force is so small that it can be computed only from long-term systematic changes. For Echo I this force is about 1/50 of an ounce. For grapefruit-sized Vanguard I (slide 21), it is only three ten-millionths of an ounce. This minute force of sunlight has decreased the perigee altitude of Vanguard I about 2 kilometers per year.

The Shape of the Earth

Now let's come right down to Earth. Though it may seem surprising, this little Vanguard I satellite circling above the

Earth has told us some things about the Earth's shape, structure, and history that we had not learned from standing on, traveling on, or probing its surface. Vanguard I has been in orbit and transmitting signals since March 1958. After more than 4 years in orbit its solar-powered radio is still transmitting. Tracking observations are still made six times each day.

The next slide (slide 22) shows the perigee altitude during the first couple of years. I have already explained that the pressure of solar radiation has been computed from the long-term trends. Now, what looks here like scatter of data is shown on the next slide (slide 23) to define a systematic curve. After the effects of air resistance and of the gravitational attraction of the Sun and the Moon are accounted for, the remaining orbital variations are blamed largely on irregularities in the Earth's gravity field. The geodesists, then, calculate the shape of the Earth's mass from these orbits. Two interesting results will be described.

As one would expect, centrifugal force makes the Earth larger across the equator than across the poles, somewhat as shown (slide 24), but exaggerated, on the left. One can calculate that if the Earth were completely plastic, the equatorial diameter would exceed the polar diameter by one part in 299.8. Vanguard tells us, however, that it is flatter - that the ratio is actually one part in 298.2 rather than 299.8. What does this difference imply? First, it implies that the Earth has enough structural strength and stiffness to maintain a shape different from that for plastic equilibrium. Dr. O'Keefe of NASA has estimated that a stress of 290 pounds per square inch at the base of the mantle could maintain this excess equatorial bulge.

This result leads directly to the question, "What has made the Earth more oblate than is calculated for centrifugal force?" Well, we can calculate that if the Earth were completely plastic and if it were turning 1 revolution every 23.5 hours instead of 24, then it would have the measured oblateness. Furthermore, we know the Earth's rotation is slowing down about 0.001 second per century. This slowing down is due to the conversion of rotative energy to heat through the friction in tidal motions. If this same rate persisted through the past, the Earth revolved once every 23.5 hours about 50 million years ago. It seems likely that the Earth's excessive equatorial bulge is retained from its youth. I wish we humans could retain our youthful equatorial dimensions as well. It is fascinating to reflect how the tiny Vanguard I satellite has taught us something of the stresses inside our Earth, and something of its history 50 million years ago.

Analyzing the orbit data of the preceding slide for higher harmonics has indicated that the Earth's shape is not a true ellipsoid. It is distorted as depicted in an exaggerated manner on the right of the slide. This is the well-publicized "pear shape." This distortion of 50 feet is small compared to the

8,000-mile radius. It is small compared to familiar topographic irregularities. But look at it this way: This distortion of mass distribution corresponds to raising the sea level around the North Pole 50 feet over an area comparable in size to the Atlantic Ocean. Here is something for the geophysicists to explain.

PRACTICAL APPLICATIONS

Now, let us consider briefly a few imminent practical applications of space techniques.

Navigation

A technique that can measure the Earth as accurately as in the work just described can be useful in navigation and in improving the accuracy of maps and charts. Developments along this line are being pursued.

Meteorology

Meteorologists tell us they could predict weather changes much more accurately if they had available frequent, world-wide observations of existing weather conditions. The NASA has satellites in orbit transmitting such observations. The results are supplied to the U. S. Weather Bureau for analysis and forecasts, and are shared with the World. To date, NASA has put five Tiros (slide 25) weather satellites into orbit. Tiros satellites were originally intended as development models to aid in the design of operational weather satellites. The results have been so good that the information they are telemetering to Earth is already being used in operational weather forecasting. The next slide (slide 26) illustrates some of the cloud pictures televised by a Tiros. Note the number of hurricanes and typhoons spotted on this single day. From this particular cloud analysis, Hurricane Esther was spotted before she was detected by any other means. Warnings were issued which probably decreased the destruction of life and property. Tiros satellites also measure infrared radiation from the Earth and its clouds. (Slide 27) A sample of the results from one pass and the weather fronts deduced therefrom are shown here. Tiros V was launched into orbit on June 19 to be in service during this year's hurricane season. Its orbit ranges farther north and south to report weather developments over more of the Earth and, in addition, to report icebergs.

The next generation of weather satellites, to be called "Nimbus," is under development. (Slide 28) Nimbus satellites will carry more advanced instruments. They will fly polar orbits with their TV cameras and other instruments pointed continuously earthward. Thus, each one will report weather conditions over the entire globe twice each day. It will be interesting to learn what their observations do to the science of weather forecasting, and how mankind benefits.

Communication

Long-range wireless communication, as you know, is fickle because it depends on the reflection of radio waves from ionized layers of the atmosphere and these layers change with solar activity. Even long-distance communication through wires and cables is sometimes disrupted by magnetic storms. Communication cables are rapidly becoming overloaded. Already, the commercial communication companies tell us it will cost less to establish a system of communication satellites than to provide more cables. NASA's responsibility in this realm is for long-range research and development. We are not a communication operating agency. Congress is now determining the balance between government and private industry in the establishment and operation of this new class of communication facilities.

Passive, reflecting satellites are the simplest communication satellites. Echo I, mentioned earlier, has proven their feasibility. Echo II (slide 29), now under development, will have twice the area and will be of more-rigid construction to maintain its shape longer. After almost 2 years in orbit, Echo I is probably shaped like a prune. Passive satellites reflect signals rather weakly so they require sizable, carefully directed antennas on the ground. A number of satellites and ground stations spaced around the world would be required for continuous world-wide communication. An advantage is that passive satellites can simultaneously serve an unlimited number of users.

Active communication satellites (slide 30) receive, amplify, and retransmit signals. Thus, they send stronger signals to Earth. They are more complex and more subject to failure up there in orbit where no maintenance men are available. Several versions are under development. Telstar, the first, is scheduled for launching in the near future. A number can be placed around the Earth in low orbits and used successively as they fly over, or they can be put 22,300 miles above the Earth where their orbit time is the same as Earth's rotation time so they will stay over one area of the Earth as it rotates. Hughes Aircraft Company, of Culver City, on contract to NASA, is building Syncom, the first of this synchronous type. Its first flight is planned for early next year. In most of this address I have confined myself to scientific advances already gained from the young space age. Regarding communications, I have described some projects still in development. It won't be long until these bring us greatly expanded, reliable, world-wide communication. This will include simultaneous world-wide radio and television. I hope the programs will be wisely selected. I hope they will serve to improve understanding among the world's people.

MANNED SPACE FLIGHT

NASA's program has many fascinating aspects which, I regret, there is not time to discuss with you. One of the most fascinating is manned space flight. To report accomplishments in this mission would be to report what you have all followed. You all know too, I am sure, that President Kennedy has set the goal (slide 31) of sending a man to the Moon and home again within this decade. A large share of NASA's effort supports this national goal. Here in Los Angeles, North American Aviation has the prime contract to produce the Apollo spacecraft for this exciting mission.

As we are learning as fast as we can about the Moon and its environment for this mission, we are also studying the planets - their atmospheres, surface characteristics, the likelihood of life on these other worlds.

OTHER NASA RESPONSIBILITIES

There has not been time to discuss the boosters which send our spacecraft on their way, nor the rockets for propulsion in space, nor the guidance systems. I have not mentioned the many fascinating human and biological problems.

There has not been time to discuss aeronautics, an area in which NASA has responsibility for research and development. You are, I am sure, aware of some aspects, for example, the frequent establishment of new speed and altitude records by the X-15 airplane as a by-product of its research flights from NASA's Flight Research Center at Edwards, California. NASA research also supports the development of advanced commercial and military aircraft of all types. Supersonic bombers and transports, and, at the other extreme, improved aircraft for vertical or slow take-off and landing present exciting prospects. Now we frequently work a full day in Washington, D. C., and then are home in California at bedtime. Before many years we will have dinner in Washington, D. C., catch a 7:30 airplane, eat dinner en route, and land in California at 6:00, just in time for cocktails before dinner.

IMPLICATIONS FOR TEACHERS

Where will this explosion of science and technology lead? I assure you I do not know. A few hundred million years ago, life on this planet began to leave the protection of the marshes and venture into the hostile environment above. Now, life on this planet is just starting the next step out beyond the protection of the atmosphere. No, I don't know how this step will affect us. We can count on many problems and many benefits we can not now imagine. If, on the other hand, we do not push ahead, our nation will surely become scientifically and technologically obsolete.

Who will carry on with this exciting exploration of space and the concomitant broad advance of knowledge? Your students will! How should you science teachers prepare them? Most important of all, teach them to think. I can't tell you how; you are the experts at that task. Teach them to read with understanding and to write. For this, straight, well-organized thinking is the first requirement. In science and engineering, emphasize the fundamentals because the details of application change too rapidly. In the humanities, prepare your students for the judgments they must make as citizens. They will have to evaluate an overwhelming array of possibilities and issues in order to formulate wisely and carry out effectively National objectives.

Decrying teaching methods and results is currently a popular sport. Contrary to this trend, I see evidence that science teachers are doing an excellent job. I have been amazed at the scientific maturity of some high-school students. In May I had the pleasure of judging high-school students' entries in the National Science Fair - International at Seattle. Discussing their research projects with these leading students was a reassuring experience. I congratulate teachers who contribute to the development of such students. I must admit these students make me feel inadequate - somewhat as an old-fashioned cow must feel inadequate when she grazes in the shadows of billboards advertising milk that is pasteurized, homogenized, fortified, vitaminized, and decaloryized.

Among adult citizens, I am disturbed by how often I hear such statements as, "I can't understand that, it's scientific." Such statements express mental blocks to even the simplest, clearest scientific presentations. Now, you know that scientific phenomena, taken a step at a time, are among the easiest things to understand. Citizens of normal intelligence can understand scientific matters. They must. As science inevitably demands more and more of our National effort, citizens must understand. These citizens, through their votes, determine national policy; they determine what resources are to be devoted to the various aspects of science; they guide children in the selection or rejection of careers in science. Perhaps you can help convince the public that they can and must understand something of science to make intelligent judgments in these matters which are so vital to them.

Thank you for your attention.

LIST OF ILLUSTRATIONS

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23 Perigee height - Vanguard I (showing 3d harmonic curve)

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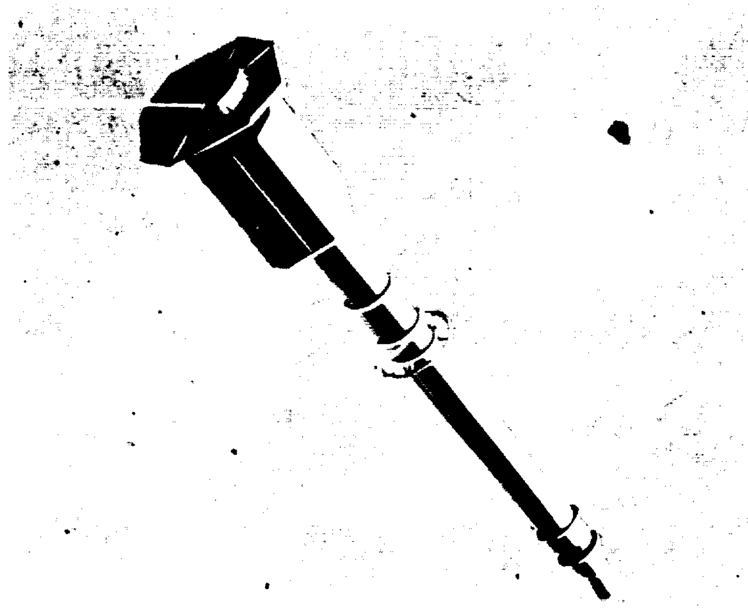
27 Frontal analysis derived from Tiros II scanning radiometer data

28 Nimbus meteorological satellite

29 Rigid sphere satellite

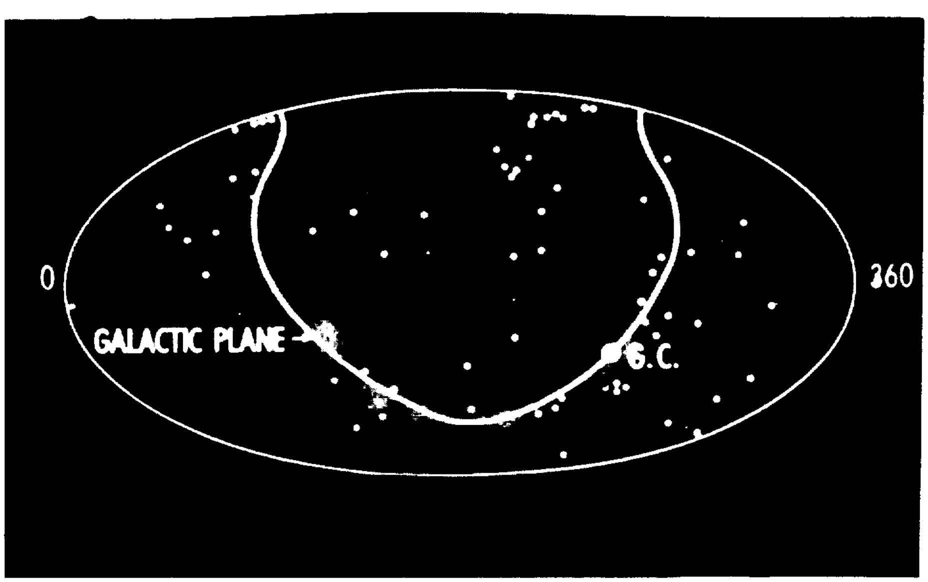
30 Active repeater satellite

31 Apollo lunar landing mission (rendezvous)



Slide 1.

GAMMA RAY EVENTS PLOTTED
ON EQUAL AREA PROJECTION



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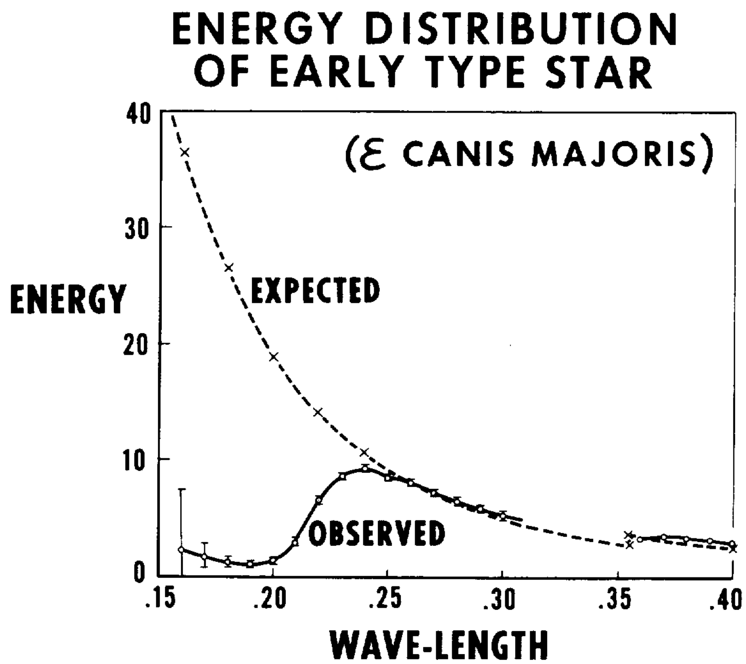

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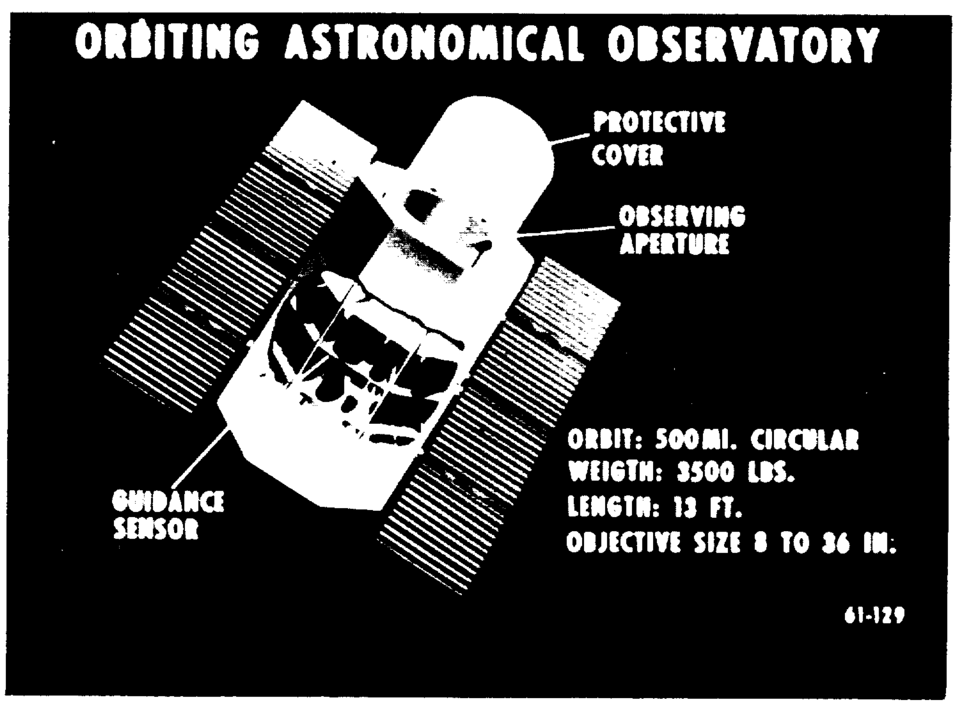
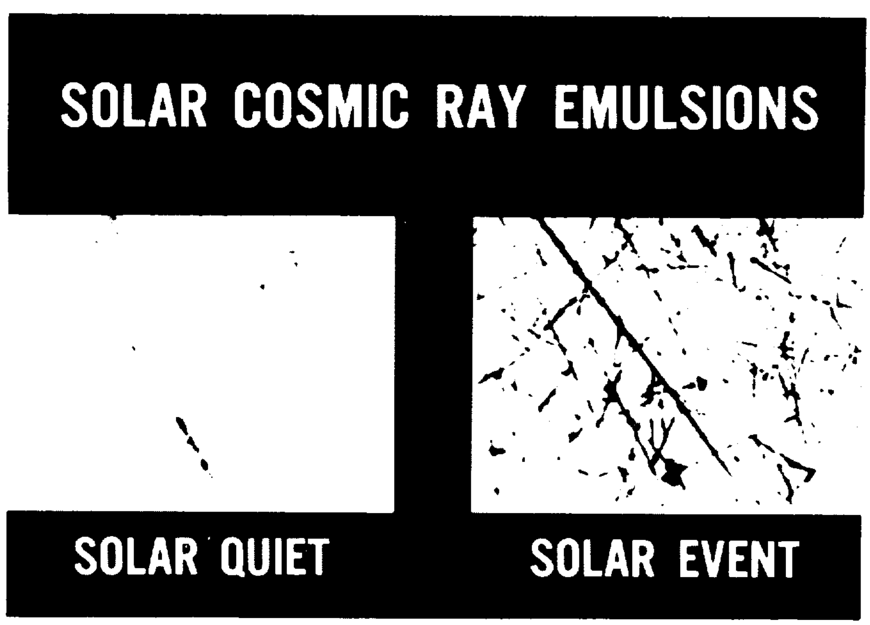


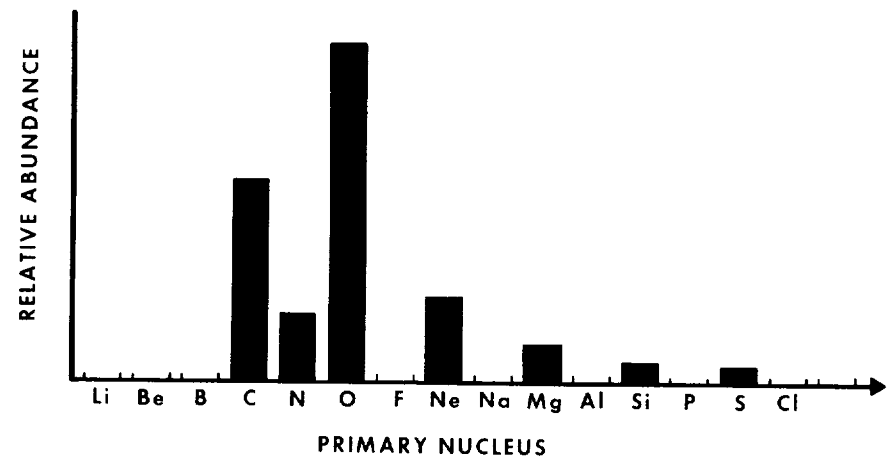
Slide 4.

Slide 5.- Sparrobee rocket launching.



Slide 6.

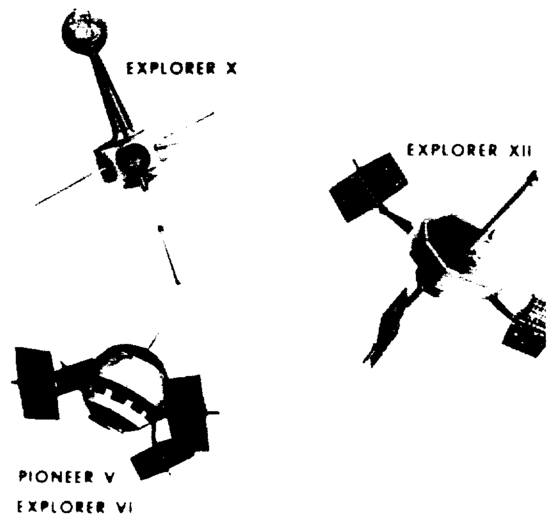
CHARGE DISTRIBUTION OF HEAVY NUCLEI IN A SOLAR COSMIC RAY EVENT



Slide 7.

SOLAR STORMS

Slide 8.



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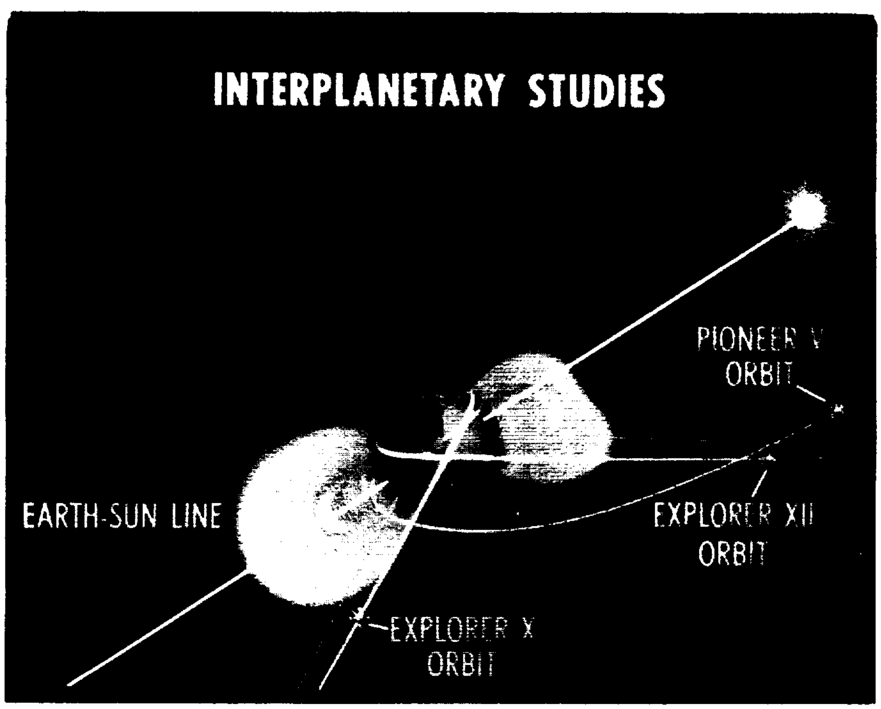

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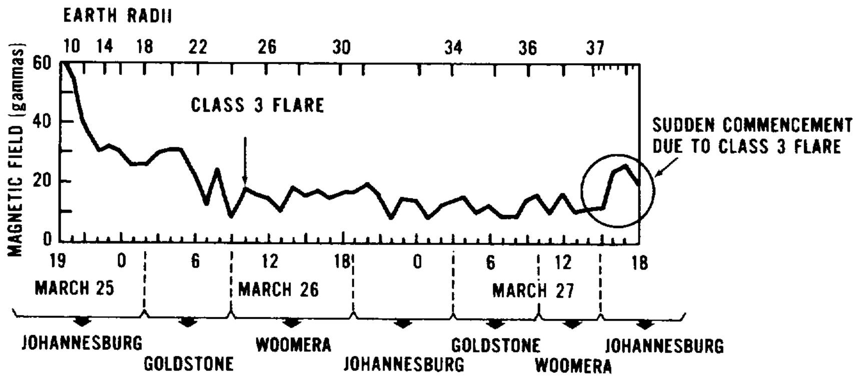
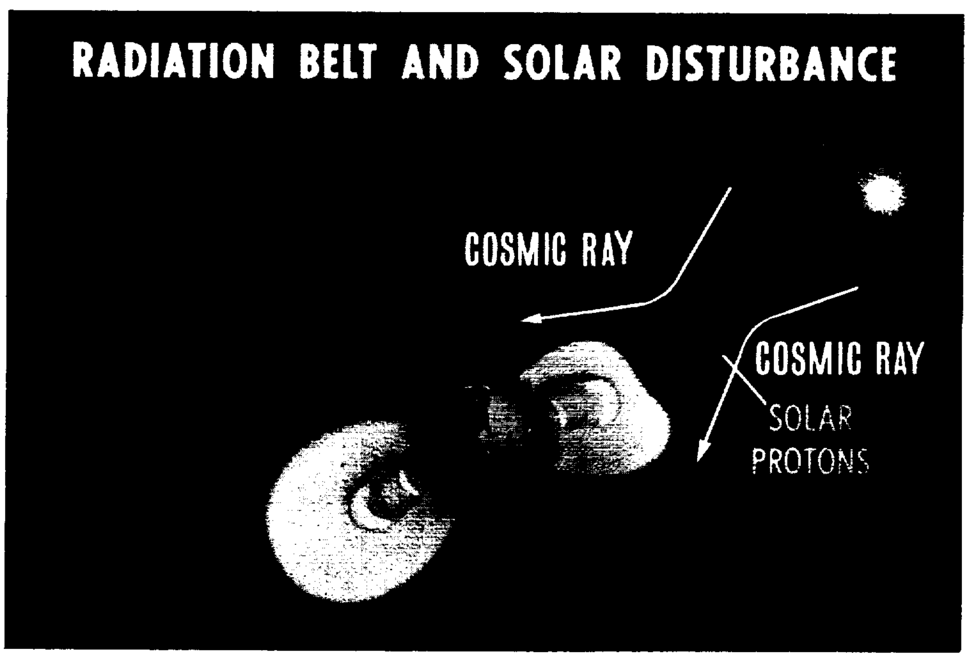
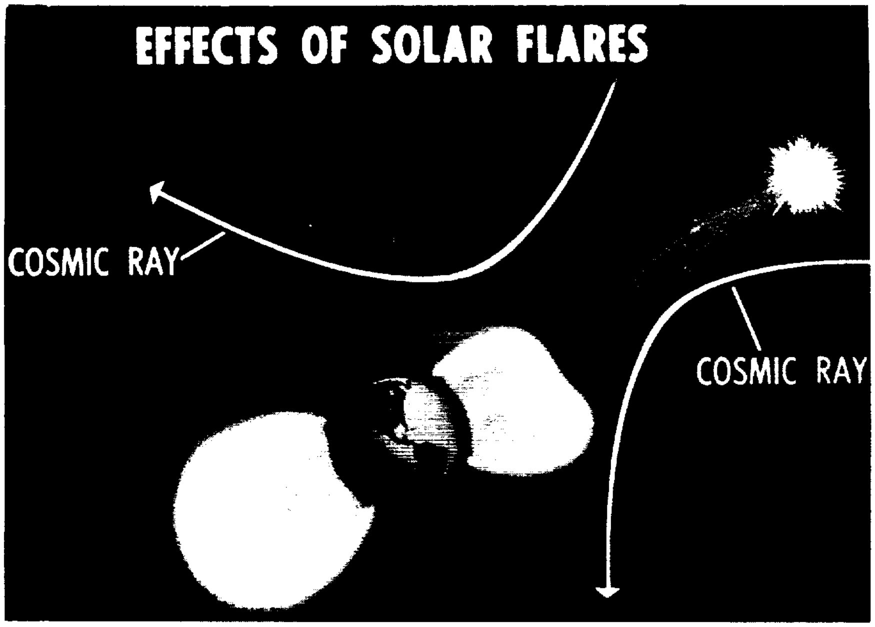


Slide 11.- Magnetometer readings from Explorer X.



Slide 12.



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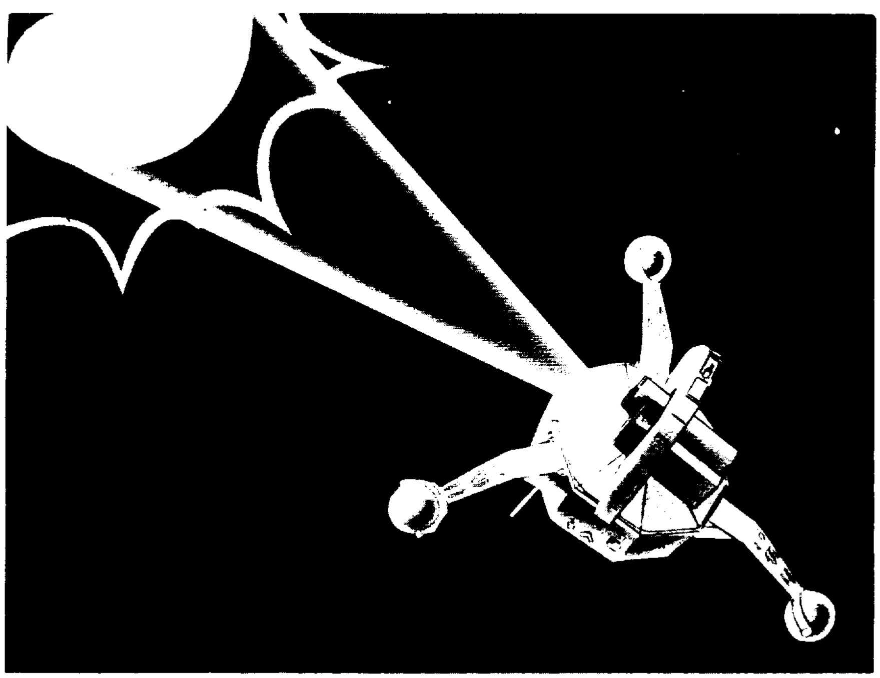
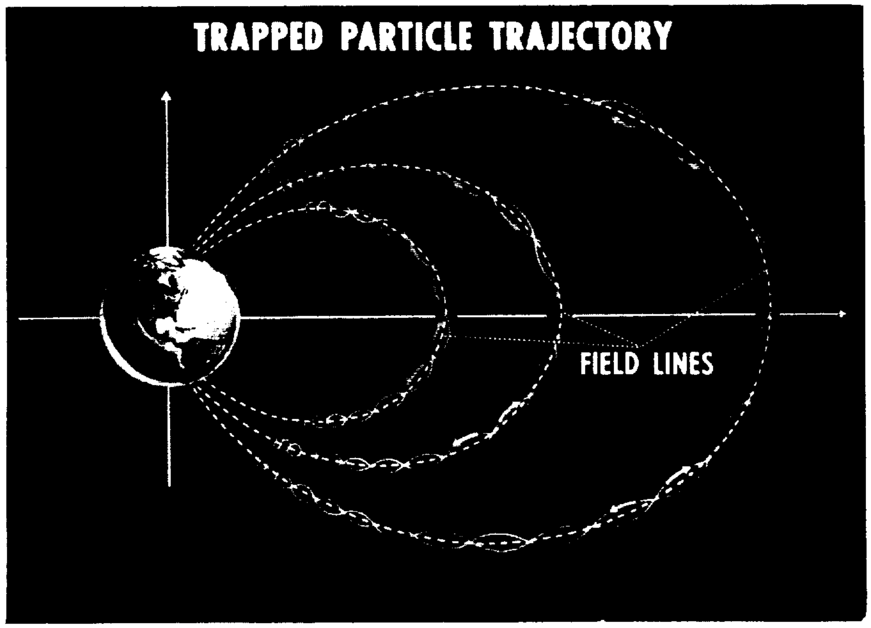


Slide 14.- Orbiting solar observatory.



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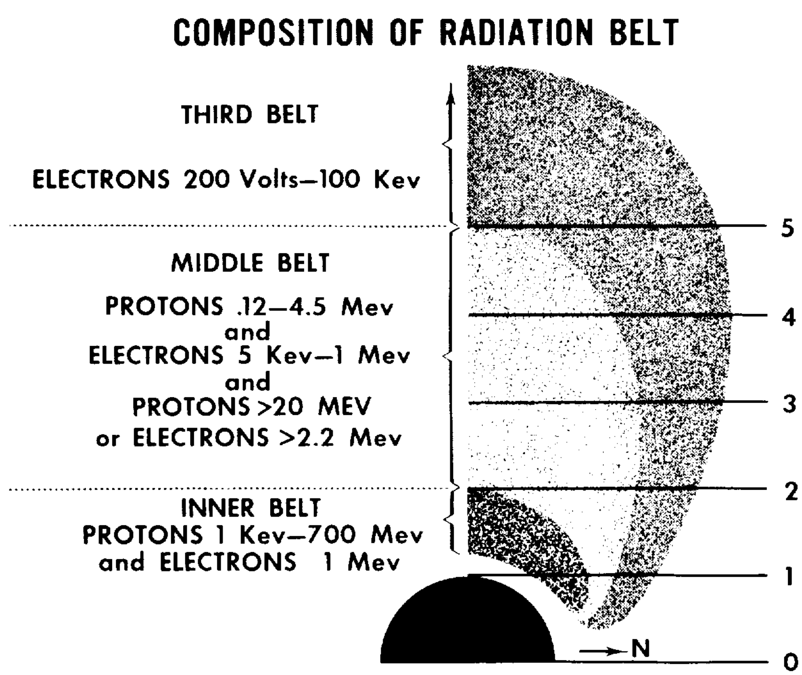

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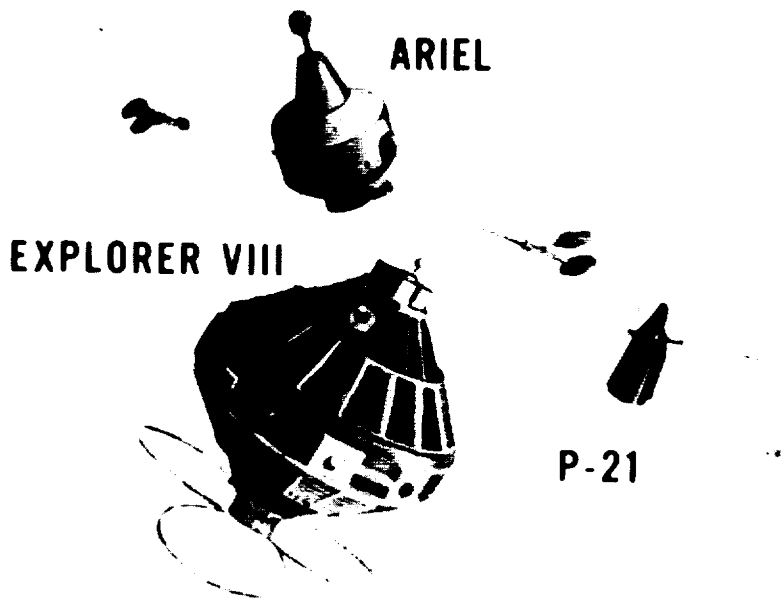

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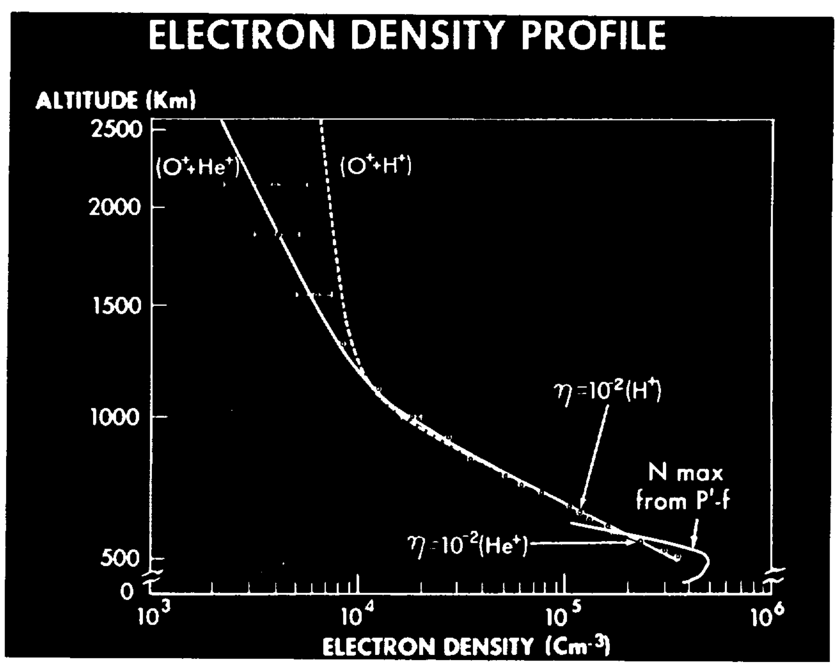
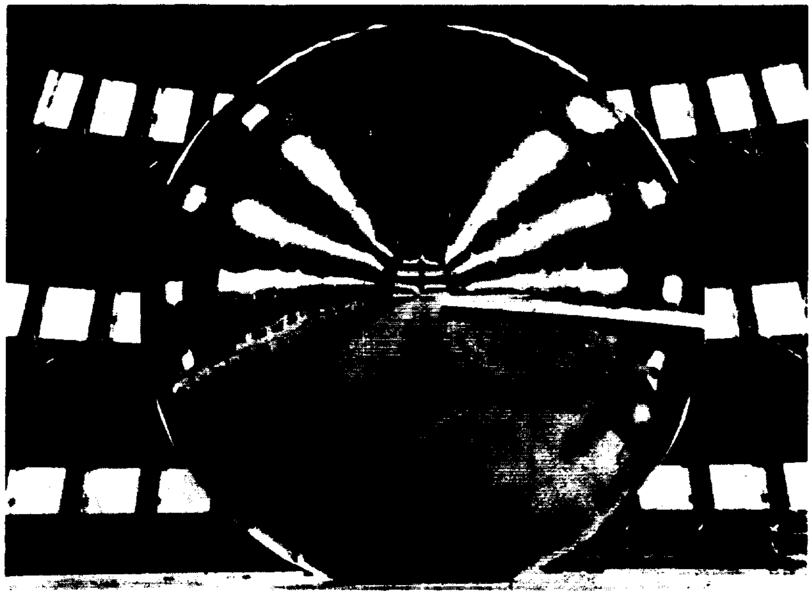


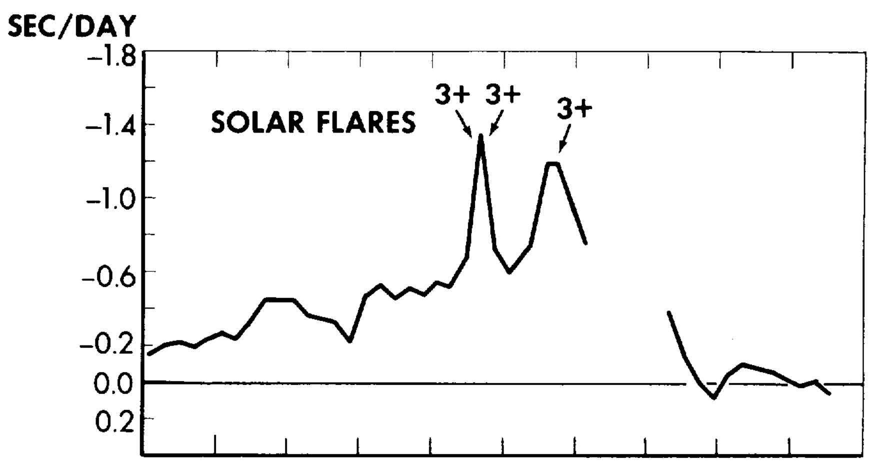
Slide 18.

100-FT. DIAMETER PASSIVE COMMUNICATIONS SATELLITE



Slide 19.

VARIATION PERIOD OF ECHO 1



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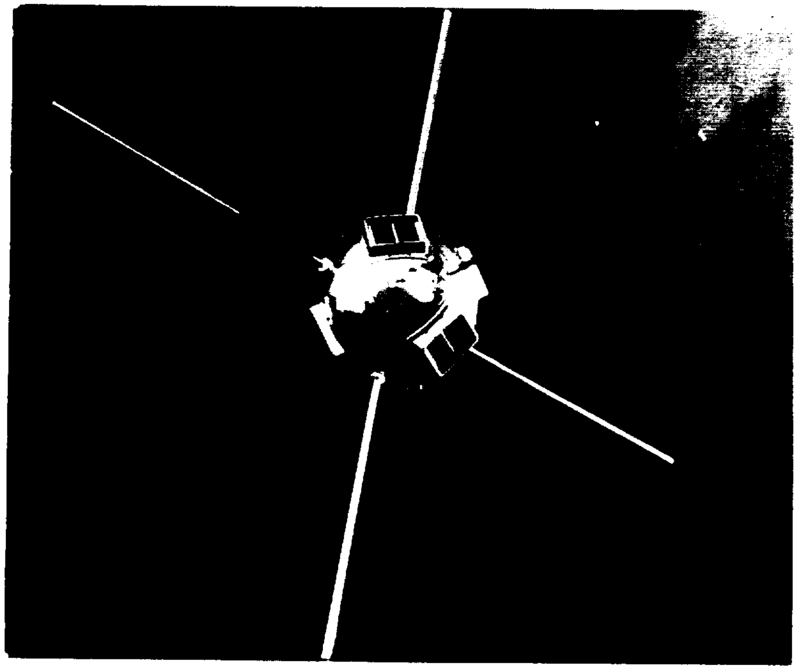

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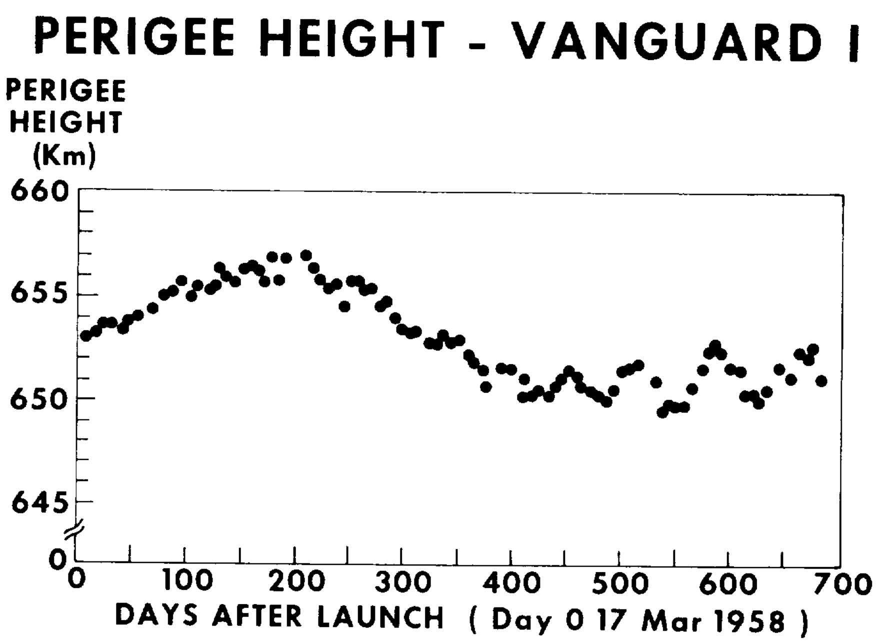
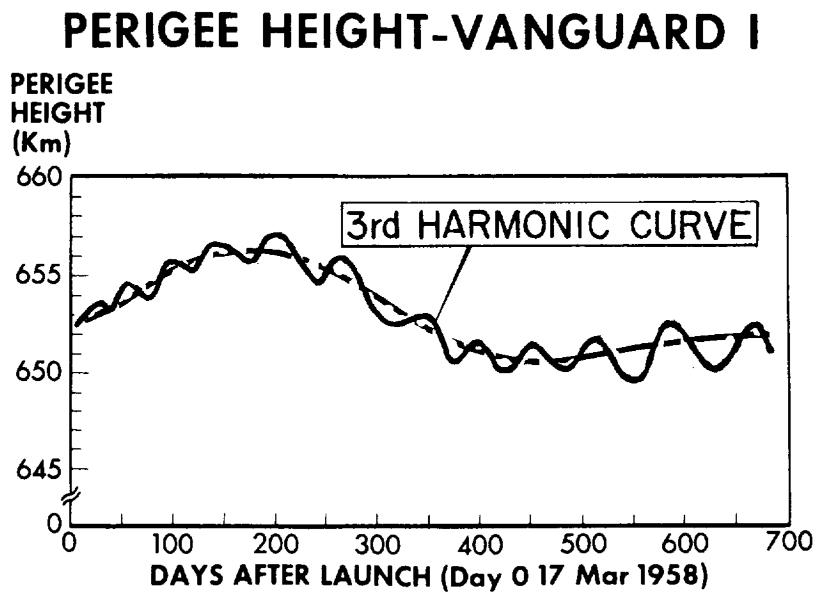
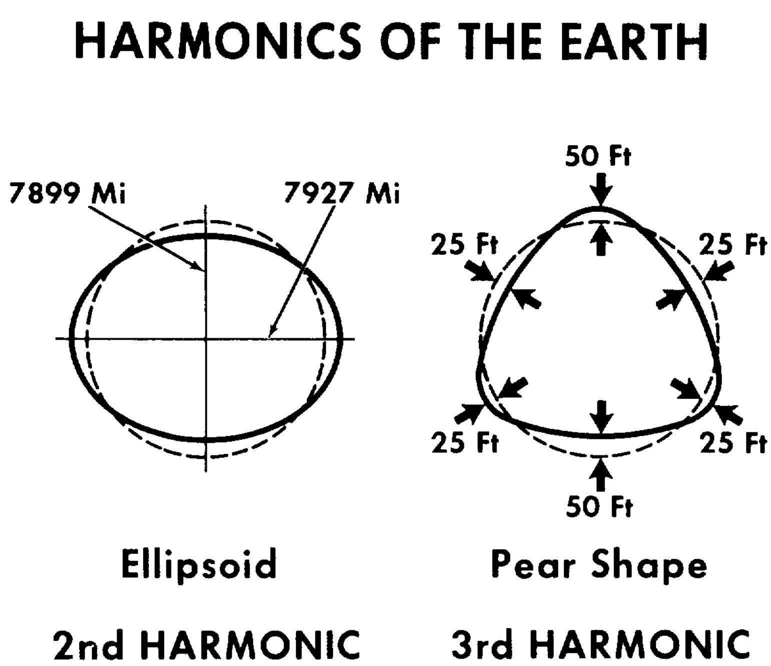


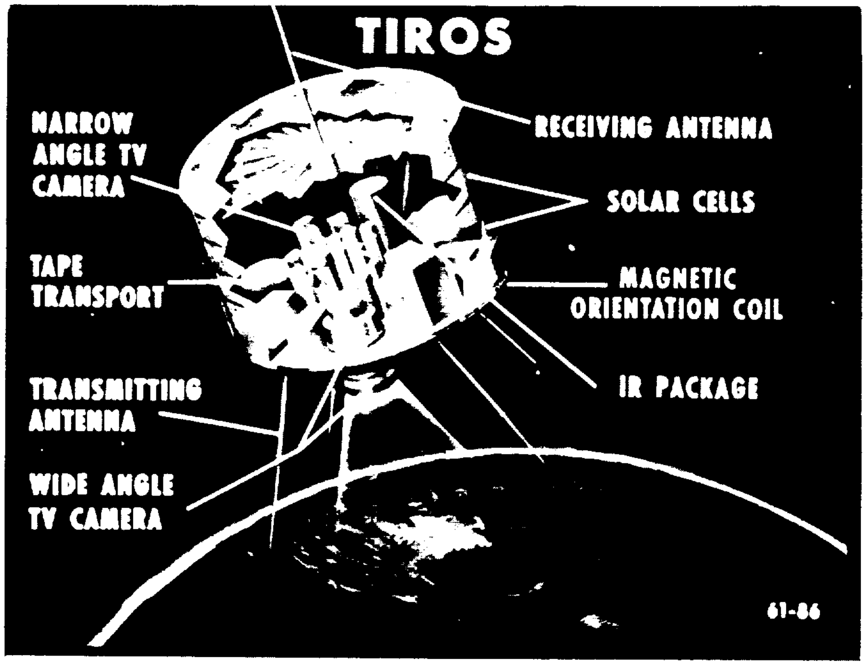
Slide 22.



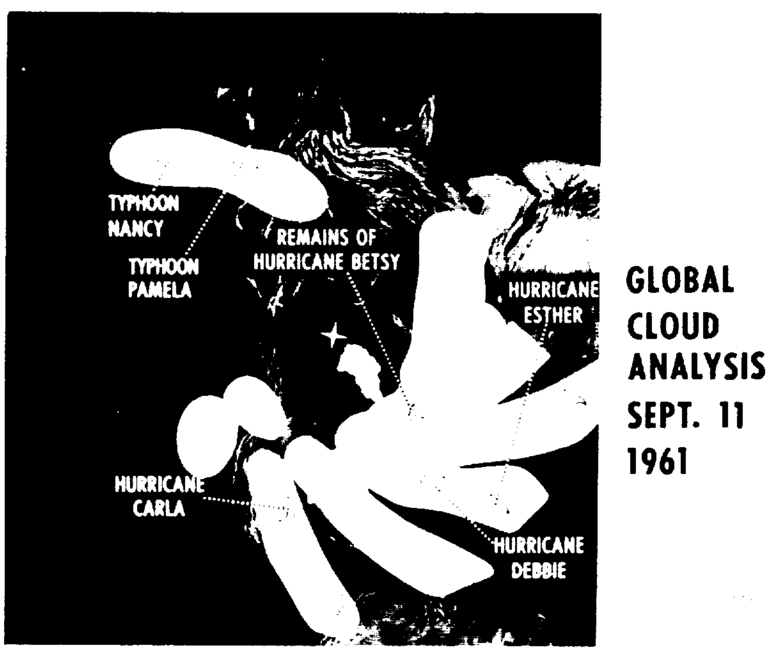
Slide 23.



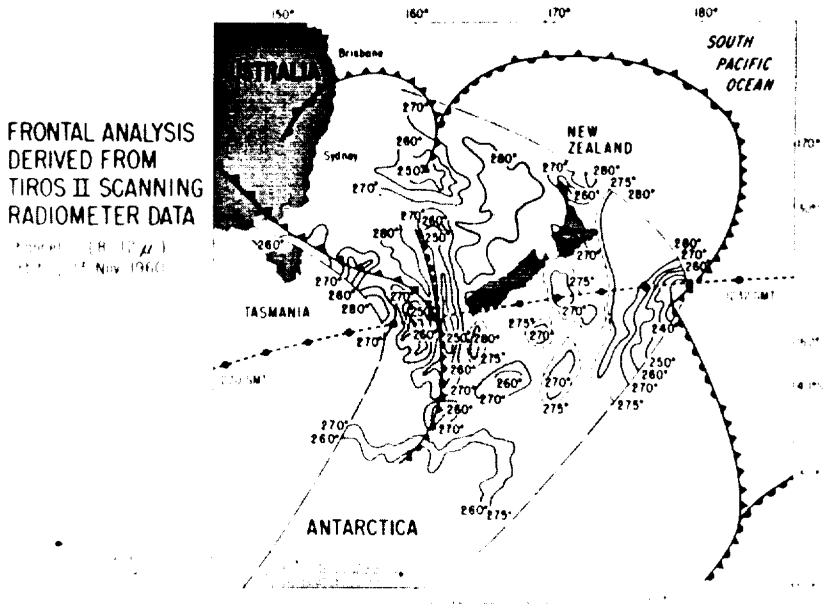
Slide 24.- Harmonics of the Earth.



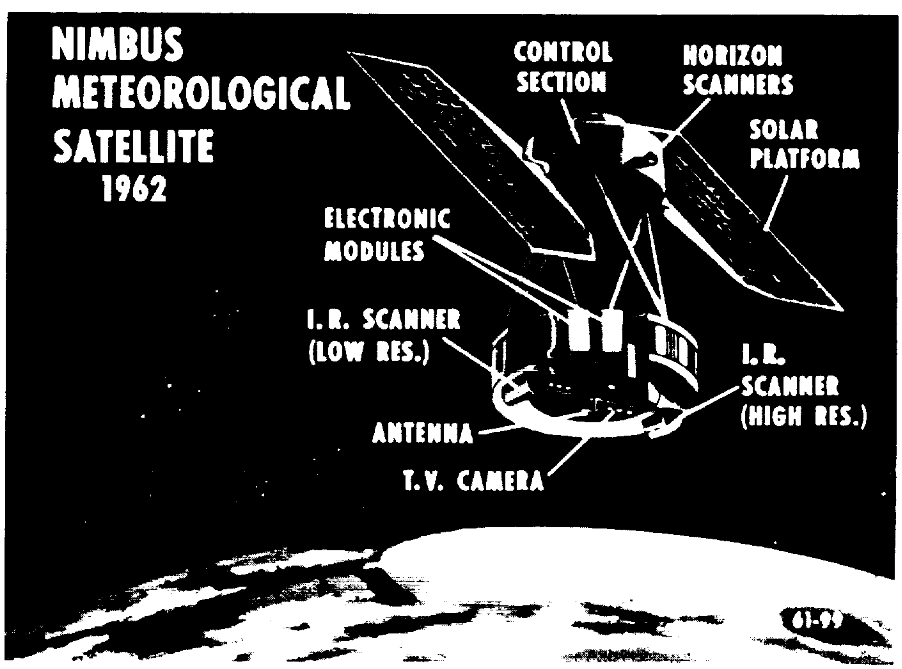
Slide 25.



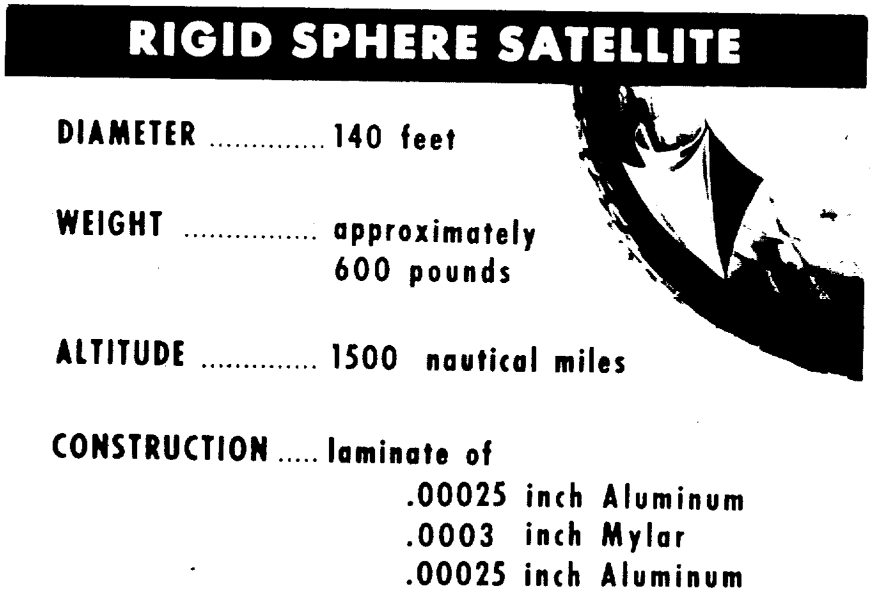
Slide 26.



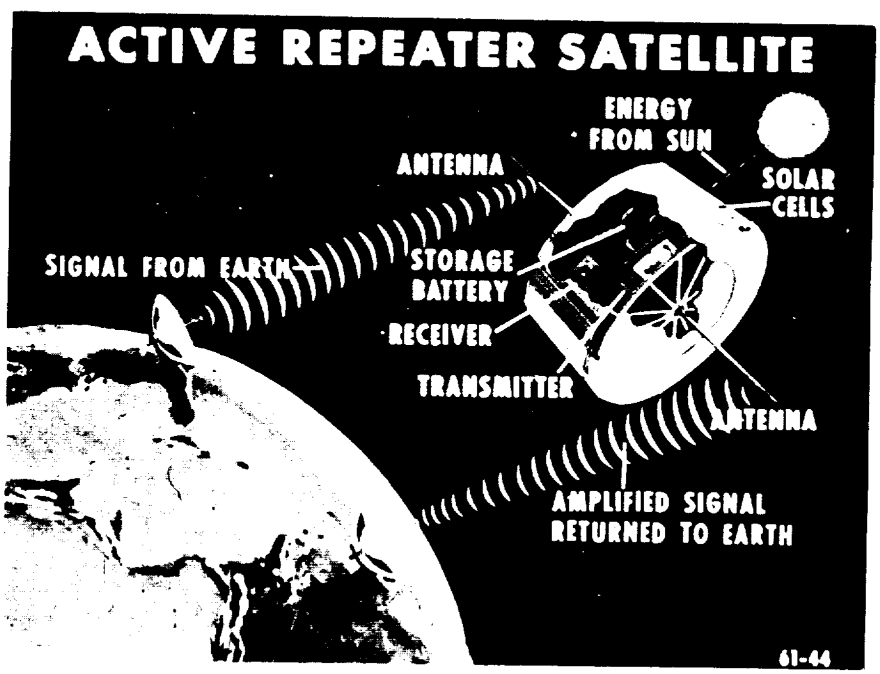
Slide 27.



Slide 28.



Slide 29.



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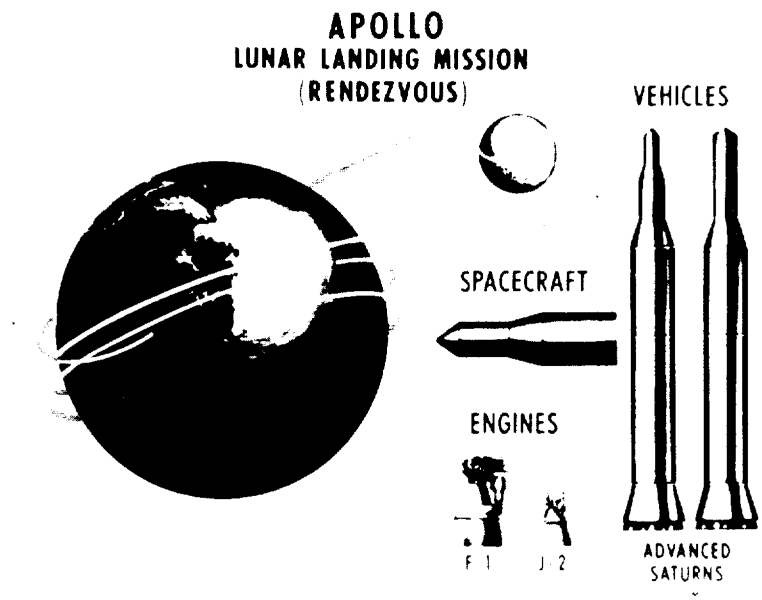
APOLLO
LUNAR LANDING MISSION
(RENDEZVOUS)
VEHICLES
SPACECRAFT
ENGINES
F-1
J-2
ADVANCED
SATURNS

Slide 31.